· BELLCOMM, INC.
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SUBJECT: The Effect of Addition of an Experimental Film Vault on Cluster Inertial Properties and CMG Control Capability Case 620

DATE: September 9, 1969

FROM: W. W. Hough

MEMORANDUM FOR FILE

[redacted]

MSFC has indicated a requirement for a 6000 pound vault on the SWS to protect experimental film from harmful radiation during the eight-month mission of AAP-1. A question concerning the capability of two CMG's to control the Cluster in the solar-inertial mode with such an addition was raised. This question was addressed at the ML Review on September fourth; viewgraphs used in the presentation are attached.

The CMG momentum storage requirement in the solar inertial mode is due primarily to the cyclic component of gravity-gradient torque. This cyclic component (vector) is always directed normal to the orbital plane, and its magnitude is directly proportional to the difference between the maximum and minimum vehicle inertias about vehicle axes that lie in the orbital plane. It is therefore highest (at a given orbital position) when the vehicle principal axes of maximum and minimum moments of inertias lie in the orbital plane. In Figure 2, it is shown that the CMG momentum storage requirement due to the cyclic gravity-gradient torque is the integral of the torque over the time to complete one quarter of the orbit, and the worst-case momentum storage requirement is also directly proportional to the difference between the maximum and minimum principal moments of inertia.

Initially, MSFC mass-properties data was used as a base for determining inertia differences. However, it was noted that the MSFC data included a 34,000 pound CSM when the CSM weight reported by MSC is 28,555 pounds. Therefore, modified mass-properties data, corrected for the lighter CSM, was used as a second data base. The film vault was positioned at 12 different locations in the SWS, and listed in Figure 3 are the inertia differences for the two data bases, and for these plus a 6000 pound film vault in the locations that give the least and the greatest increases in the differences.

In Figure 4, the linear relationship between the momentum storage requirement and the inertia difference is plotted and the data points from Figure 3 are noted. All cases are seen to be within the capability of two CMG's. When the

requirement is increased to account for aerodynamic torque and bias momentum accumulation, and the 8000 ft. lb. sec. capability is reduced to account for the possibility of encountering CMG gimbal stops, the 2-CMG control margin (with the heavy CSM and worst case vault) is approximately 18%. This is not considered a big margin at this point in the SWS program, and it is therefore concluded that greater attention must be paid to growth in vehicle inertias as the program evolves. It is also noted that the effect of additions on the control requirement can be minimized by locating the addition close to the vehicle center of gravity.

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W. W. Hough

Attachments

CMG MOMENTUM STORAGE REQUIREMENTS VS. CAPABILITIES

CMG OPERATION

- ANGULAR MOMENTUM OF ONE ROTOR = 2000 FT LB SEC
- TWO CMG'S REQUIRED TO GIVE ARBITRARY CONTROL TORQUE
- MAXIMUM MOMENTUM STORAGE CAPACITY OF TWO CMG'S = 8000 FT LB SEC (-4000 ⟶ + 4000)

MOMENTUM STORAGE

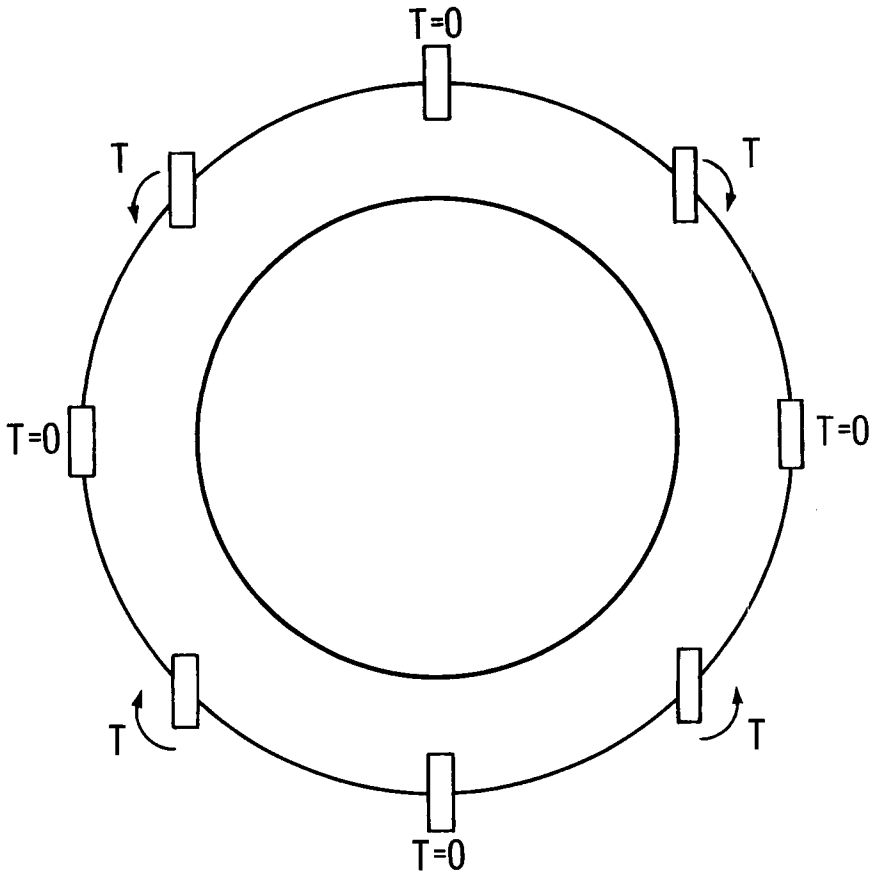
- STORAGE REQUIREMENT A FUNCTION OF VEHICLE ATTITUDE AND PRINCIPAL MOMENTS OF INERTIA
- IN SOLAR INERTIAL ATTITUDE, GRAVITY GRADIENT TORQUE IS MAJOR DISTURBANCE
- PEAK STORAGE REQUIREMENT DUE TO GRAVITY GRADIENT TORQUE IS DIRECTLY PROPORTIONAL TO DIFFERENCE BETWEEN MAXIMUM AND MINIMUM MOMENTS OF INERTIA

ADDITION OF 6000 LB FILM FAULT

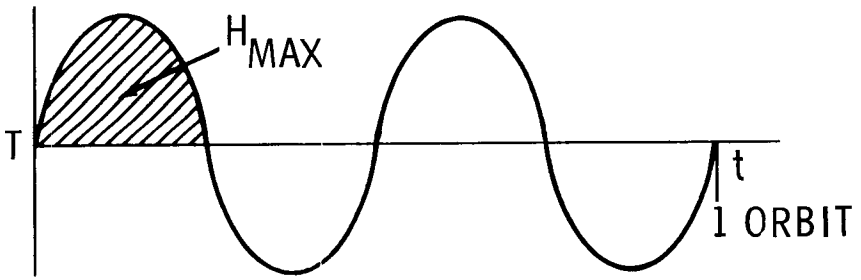
- FILM VAULT INCREASES INERTIA DIFFERENCES (EXCEPT AT CG)
- TWELVE LOCATIONS OF FILM VAULT ANALYZED
- POSITIONS GIVING MINIMUM AND MAXIMUM INERTIA DIFFERENCES LISTED
- MSFC INERTIA DATA CORRECTED FOR ACTUAL CSM WEIGHT

Figure 1

CMG MOMENTUM STORAGE REQUIREMENTS
GRAVITY GRADIENT TORQUE IN SOLAR INERTIAL MODE



$$T = \frac{3\omega^2}{2}\left(I_{MAX} - I_{MIN}\right) \text{ SIN } 2\,\omega t$$



$$H = \int T\,dt$$

$$H_{MAX} = \int_0^{\pi/2\omega} T\,dt = \frac{3}{2}\,\omega\left(I_{MAX} - I_{MIN}\right)$$

Figure 2

INERTIA DIFFERENCES

	WEIGHT (LBS)	$I_{MAX} - I_{MIN}$ (SLUG FT^2)
MSFC DATA (34,000 LB CSM)	141,595	3,351,232
PLUS 6000 LB FILM VAULT IN MDA ON −Y AXIS	147,595	3,361,879
PLUS 6000 LB FILM VAULT IN SWS CREW QUARTERS ON +Z AXIS	147,595	3,597,102
CORRECTED DATA (28,555 LB CSM)	136,150	3,044,204
PLUS 6000 LB FILM VAULT IN MDA ON −Y AXIS	142,150	3,060,001
PLUS 6000 LB FILM VAULT IN SWS CREW QUARTERS ON +Z AXIS	142,150	3,269,215

Figure 3

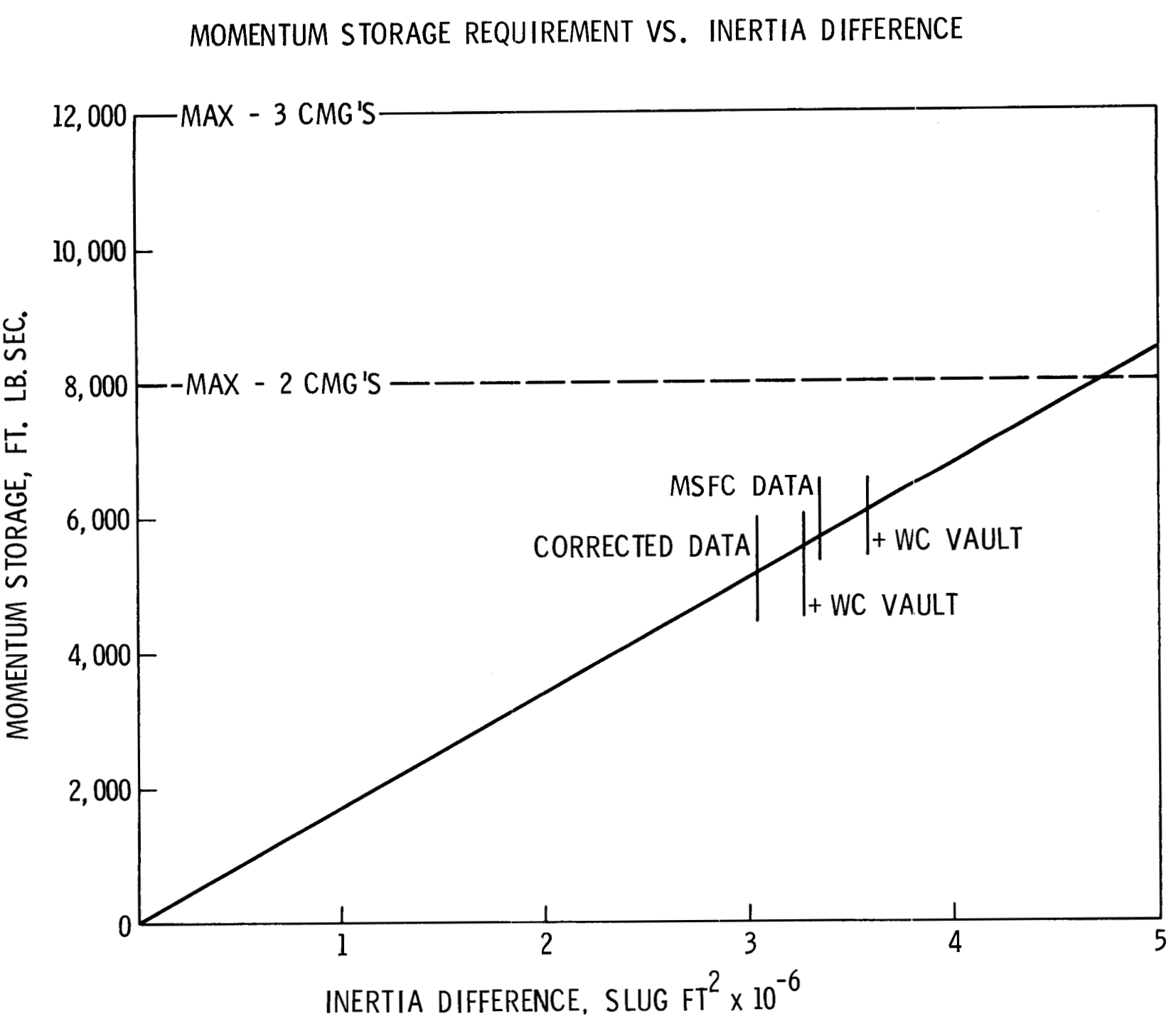

MOMENTUM STORAGE REQUIREMENT VS. INERTIA DIFFERENCE
12,000
MAX - 3 CMG'S
10,000
8,000
MAX - 2 CMG'S
6,000
4,000
2,000
0
MOMENTUM STORAGE, FT. LB. SEC.
MSFC DATA
CORRECTED DATA
+ WC VAULT
+ WC VAULT
1
2
3
4
5
INERTIA DIFFERENCE, SLUG FT^2 x 10^{-6}

Figure 4

CONCLUSIONS

- ADDITION OF FILM VAULT INCREASES INERTIA DIFFERENCES, AND THERFORE MOMENTUM STORAGE REQUIREMENT, BY MAXIMUM OF 7 1/2%
- ALL CASES ANALYZED ARE WITHIN CAPABILITY OF TWO CMG'S
- EFFECT OF FILM VAULT AND OTHER ADDED COMPONENTS ON CONTROL REQUIREMENT CAN BE MINIMIZED BY LOCATING COMPONENT CLOSE TO CG (1 FOOT FORWARD OF PS SEPARATION PLANE)
- MARGIN ON TWO CMG CONTROL CAPABILITY IS NOT GREAT. GROWTH IN VEHICLE INERTIAS MUST BE LIMITED TO MAINTAIN CONTROL CAPABILITY WITH TWO CMG'S

Figure 5

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From: W. W. Hough

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